COMMUNICATION BY ELECTRICAL STIMULATION OF THE SKIN

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Prepared by

UNIVERSITY OF LOUISVILLE
Louisville, Kentucky

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, Washington, D. C.

January 14, 1967

Semi-Annual Progress Report
1 May 1966 - 31 October 1966

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Introduction

The work during the six months covered in this report has been directed toward the attainment of the objective as stated in the Summary of the progress report for the preceeding report period. "When it (electrocutaneous code training) resumes, Ss will be taught a new "final" code, the construction of which has been guided by the experience gained with the previous codes" (Foulke & Sticht, 1966). This objective is the cumulation of several years of research and development (Foulke, 1962; Foulke, 1963; Foulke, 1965; Foulke & Sticht, 1966).

Briefly, the code progressed from a three dimensional electrocutaneous code that made use of two intensities, two durations and ten locations to form signals which represented the letters in the English alphabet, to a code in which intensity and duration are held constant and signals are composed of patterns of simultaneously stimulated locations. The signals in this code stand for the elements in the Japanese Katakana Syllabary (Foulke & Sticht, 1966). The purpose of this undertaking is the development of an electrocutaneous code for the communication of the English language at a useful rate.

In the work immediately preceeding the present report period, four different codes, with location patterns as signals, were compared in order to provide a reasonable basis for the construction of a final code. Stimulus intensity and duration were held constant, and only the number and arrangement of locations were varied from signal to signal. The response alphabet consisted of the elements in the Katakana Syllabary and native Japanese served as Ss. It was found that patterns including palmar locations were involved in error too frequently to be considered for use in an efficient code. It was therefore concluded that the locations used in composing the signals of the final code should be restricted to the fingertips. As a result of experience and consultation, it was also decided to replace DC pulses with AC pulses as stimuli.

Work In Progress

Activity during the current reporting period can be divided into four phases: Modification of Apparatus, Determination of Signal Parameters, Composition of the Final Code, and Code Learning. These topics will be covered in the following paragraphs.

Modification of Apparatus.-Experience revealed difficulty with the final code sending apparatus described in Part II of the preceeding progress report (Foulke & Sticht, 1966). There was a lack of independence of the intensities of stimuli at various locations, so that the intensity of a signal depended upon the number and arrangement of stimulated locations. Also, Ss reported a fluctuation in stimulus intensity that appeared to be related to the electrodes described in this section. In view of these considerations, the following modifications were made.

The amplifier chassis described in the apparatus section referred to above was replaced with a chassis containing ten amplifiers, one for each location to be stimulated. The output of each of these amplifiers is connected permanently to one, and only one electrode assembly, thus eliminating troublesome switching complexity. The electronic logic, described in the preceeding report, is used to turn on and off these amplifiers in appropriate combinations.

Each electrode assembly now consists of only two electrodes, the heads of ordinary round head screws. As before, the electrode assemblies are mounted in slots on handboards and their positions can be adjusted to meet the requirements of individual hands.

Determination of Signal Parameters.-Four parameters of an AC sinusodial stimulus that may be varied conveniently are its intensity, frequency, rise time, and duration. At present, as in the past, Ss are instructed to adjust intensity for personal comfort. Because there was a possibility that a particular combination of duration frequency and rise time might result in significantly more accurate identification of stimulus patterns, pilot studies were conducted in which Ss were required to identify, by naming the stimulated locations, patterns presented by E. The Ss in these studies were three project members with considerable experience in identifying such patterns. Three-location patterns were used since, if a particular combination of stimulus parameters made a difference, this difference would probably be manifested in the identification of the most difficult patterns to be used in the code.

Testing consisted of presenting the group of three-location patterns that can be formed by stimulating two fingertips on the left hand and one fingertip on the right hand for identification by the three Ss. The composition of stimuli, with respect to frequency, duration and rise time, was changed from trial to trial. Comparison of the record of the three Ss revealed that most satisfactory performance was obtained with stimuli at a frequency of 400 cps, a rise time of approximately .5 msec. (milliseconds), and a duration of either five or twenty-five msec. There was a slight difference in favor of the twenty-five msec. duration which was, however, not significant. This duration was chosen, nevertheless, because the apparatus functions more dependably when it is used.

Composition of the Final Code.-Experience with the four previous codes had indicated that the following considerations should be taken into account in assigning meanings to location patterns in the final code: (1) stimulus locations should be restricted to fingertips, (2) patterns identified with the greatest accuracy are those involving only one stimulated location, (3) patterns with two stimulated locations ranked second with respect to accuracy of identification, and it was found that, in general, two location patterns were identified more accurately when the locations were widely separated, and (4) though three-location patterns were frequenly misidentified, accuracy of identification could be significantly improved by distributing the three-location to be used between the two hands. The facts just presented were taken into account by assigning the most frequently occuring characters in the Katakana alphabet to the location patterns that could be identified most accurately. In this connection, the advice of Mr. Hiroshi Tanamachi, a project member who is himself a native Japanese, was relied upon. The Katakana Syllabary contains 76 characters, and, upon the advice of Mr. Tanamachi, provisions were made for four punctuation marks. Meanings were assigned to all of the one and two-location patterns before any three-location patterns were used. Forty-five three-location patterns were required to complete the code.

Since there are 100 three-location patterns that can be formed, using two locations on one hand and one on the other, a pilot study was conducted to provide a basis for choosing the forty-five three-location patterns that were required. Using the apparatus and procedure described earlier, the fifty patterns involving two locations on the left hand and one location on the right hand were tested for accuracy of identification. Two project members served as Ss, and each S made ten observations of each of the fifty patterns. Thus, each pattern was observed twenty times, and there were 1,000 observations in all. Since, for each S, the ten possible pairs of locations on the left hand were stimulated ten times in conjunction with each of the five locations on the right hand, and since there were two Ss, there were 100 observations of each pair of stimulated locations on the left hand. For each set of 100 observations of a pair of stimulated locations on the left hand, the fraction of erroneous observations expressed as a percent is shown in Table I.

TABLE I

Stimulus Patterns	Total % Wrong
L15	56
L14	39
L13	59
L12	58
L25	50
L24	36
L23	28
L35	29
L34	25
L45	12

The data summarized in this Table provide a clear-cut basis for choosing location patterns to be used in the code. The best pairs of locations on the left hand were L45, L34, L35, and L23.[1] And the twenty three-location patterns in which these four pairs were involved were included in the code. The erroneous observations of locations on the right hand constituted only 0.7 percent of the entire 1,000 observations, and, hence, this source of error was regarded as negligible.

This experiment was repeated, using pairs of locations on the right hand and single locations on the left hand. The data are summarized in Table I

[1] In the scheme used to designate location patterns, the letter refers to the hand stimulated (L=left, R=right) and the number refers to the fingertip stimulated (1=little finger, 2=ring finger, etc.).

TABLE II

Stimulus Patterns	Total % Wrong
R15	18
R14	38
R13	88
R12	22
R23	46
R24	46
R25	26
R34	24
R35	8
R45	4

Again, it can be seen that there is a definite basis for choosing pairs of locations. The findings presented in Table II were taken into account in choosing pairs of locations on the right hand for use in the code. Also, discrepancies in the performance of the two Ss who served in this experiment were considered. Only those pairs of right hand locations that were relatively free from error in the performance of both Ss were chosen. Application of the two criteria of relative freedom from error and intersubject agreement resulted in the selection of the following pairs of right hand locations: R14, R23, R24, R34, R35, and R45.

The fact that there is a lack of agreement between the left and right hand regarding the pairs of stimulated locations that can be most accurately identified is an interesting finding that may be worth pursuing at a later time. However, this lack of agreement was felt to be of little consequence in the present case and so the 20 three-location patterns involving the four pairs of right hand locations just mentioned were included in the code.

Code Learning.-The composition of signals in the final code is shown in Table III.

Eight Japanese Ss have now received an average of 13 code learning sessions. Sessions are conducted in the manner described in the proceeding progress report, with two exceptions. First, a syllable test covering all previously learned syllables precedes the word test associated with training on each column of characters in the syllabary. Also, it was decided to provide incentive for good performance in the form of small monetary rewards. A system of rewards has been devised according to which the magnitude of a S's reward depends upon the quality of his performance. As training progresses, the criteria for rewardable performance will be made more stringent. Informal observation suggests that the system of rewards has had the desired effect upon performance.

TABLE III

KATAKANA SYLLABARY FINGERTIP LOCATIONS

1	2	3	4	5	6	7	8	9	10	11
A R1	KA L1 R1	SA L2 R1	TA L3 R1	NA L1	HA L4 R1	MA L1R45	YA L45	LA L1R34	WA R23	WN R35
I R2	KI L1 R2	SI L2 R2	TI L3 R2	NI L2	HI L4 R2	MI L2R45	I R2	LI L2R34	I R2	゛ R45
U R3	KU L1 R3	SU L2 R3	TU L3 R3	NU L3	HU L4 R3	MU L3R45	YU L34	LU L3R34	U R3	。 R34
E R4	KE L1 R4	SE L2 R4	TE L3 R4	NE L4	HE L4 R4	ME L4R45	E R4	LE L4R34	E R4	< R24
O R5	KO L1 R5	SO L2 R5	TO L3 R5	NO L5	HO L4 R5	MO L5R45	YO L35	LO L5R34	O R5	(Repeat)
										ー R14
										(Long Sound)

12	13	14	15	16
GA L34R1	ZA L23R1	DA L35R1	BA L5 R1	PA L45R1
GI L34R2	ZI L23R2	DI L23R2	BI L5 R2	PI L45R2
GU L34R3	ZU L23R3	DU L23R3	BU L5 R3	PU L45R3
GE L34R4	ZE L23R4	DE L35R4	BE L5 R4	PE L45R4
GO L34R5	ZO L23R5	DO L35R5	BO L5 R5	PO L45R5

Subjects appear to be making better progress with the "final" code than with the four preliminary codes. Also, all Ss are now working on a single code so that, when conclusions regarding its merit are drawn, they will be based upon a much larger sample of performance data. The data regarding the course of learning that have been accumulated so far, will not be presented in this report. It was decided to postpone analysis until enough data were available to permit more definite conclusions regarding the utility of the code.

Other Project-Related Activities

Since the submission of the last report, Dr. Thomas G. Sticht has withdrawn from the project in order to accept a NASA Post Doctoral Fellowship at the University of Pittsburgh, where he is studying the sensory properties of the skin.

On September 1 of last year, Miss Ruth Ann Overmann joined our staff. She is also a first year graduate student in the Department of Psychology at the University of Louisville and a recent graduate of Webster College in Webster Groves, Missouri. She is the principal assistant, and has been given responsibility for the supervision of data collection and analysis.

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